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The Influence of Historically Marginalized Undergraduate Students' Perceptions of STEM on their Academic and Career Choices

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Abstract

Research has shown that university students approach STEM fields with preconceived notions that has the ability to influence their future STEM trajectories. Several scholarly investigations have explored pedagogical methodologies that not only recognize but actively validate the varied proficiencies that these pupils possess. This nested mixed methods study contributes to this work. Data sources included a survey, a card sorting activity, and student written reflections. By employing a thematic data analysis framework, the results indicated that students held the following perceptions of STEM: (1) STEM is task-oriented; (2) STEM is bound together by external ties; and (3) STEM is both optimistic and cognizant of the journey ahead. These results highlight the correlation between the perceptions and experiences of marginalized students in STEM. The study's implications suggest that to address the obstacles presented by external factors that hinder the acknowledgment of underrepresented students in STEM fields, policymakers, and academic institutions should take proactive steps to establish mitigation strategies.

Introduction

Despite efforts to increase the engagement and participation of underrepresented students in science, technology, engineering and mathematics (STEM) fields, gaps are still evident (Arcidiacono et al., 2016). Although the number of historically marginalized students entering these STEM educational pathways is increasing, these students do not remain in those pathways at the same rate as their White peers (Hamrick, 2019; Singer et al., 2020). This is due, in part to, marginalized students in STEM majors having difficulty leveraging their positionality and finding relevance to their lives and intersectional identities in the university classrooms (McClain & Colina Neri, 2022).

Although empirical research has shown a relationship between historically marginalized students' experiences and their levels of engagement and retention in STEM environments (Atkins et al., 2020; Collins, 2018; Dou & Cian, 2020), empirically-based understandings of the nuances and complexity of those perceptions and how they are influencing those experiences remain elusive. This study aimed to examine the relationship between how historically marginalized students perceive STEM and its influence on their professional choices. The following research questions guided this study:

1.How do historically marginalized students perceive STEM?
2.What experiences do historically marginalized students identify as having an impact on their perceptions of STEM?
3. Do historically marginalized students' perceptions of STEM influence their academic and career choices?

Theoretical and Empirical Grounding

Science identity theory served as the study's theoretical foundation. In order to examine the relationships between the beliefs and perceptions of historically marginalized communities and STEM in educational settings, social identity theory and related theoretical foundations (such as science identity theory) have been used (Williams & George-Jackson, 2014; Roberts et al., 2018; Vela et al., 2020). Science identity theory is now being utilized to explain how perception and recognition can have a big impact on how disenfranchised STEM students establish their STEM identities (Avraamidou, 2020; Carlone & Johnson, 2007; Nealy &Orgill, 2020). Carlone and Johnson's (2007) science identity theoretical framework is an integration of three-dimensional components of performance, competence, and recognition. Performance is the visible manifestation of using and understanding science practices. Competence requires that the individual has a knowledge and understanding of scientific content. Recognition of having a science identity is two-fold as it requires the individual to see oneself within science and how the community itself recognizes that individual. One crucial element of the identity theory under consideration is the manner in which these characteristics might affect the level of engagement and participation of students in STEM fields, as a result of their desire to be accepted into specific social groups (Gee, 2000; Tajfel & Turner, 1979).

Various elements, such as societal, academic, and racist systems, have a significant role in shaping students' perceptions. These aspects have the potential to be modified depending on a student's desire to gain admission into STEM areas (Hazari et al., 2013). Consequently, the formation of a STEM identity is influenced by the extent to which an individual's conceptions of STEM fit with the ideologies and beliefs of other groups (Kim et al., 2018; Linn & Tate, 2005; Morton & Parson, 2018). These ideas acknowledge the influence of an individual's self-concept on their attitudes and behaviors related to seeking inclusion in particular social groups.

Research on the development of STEM identity has been demonstrated to potentially elucidate an individual's involvement and involvement in STEM disciplines (Hazari et al., 2013). The development of a STEM identity is influenced by various identities, including societal, ethnic, gender, and racial identities. The existence of numerous identities might pose a significant obstacle for underrepresented communities as they develop their science identity, particularly within STEM learning environments (Carlone & Johnson, 2007; Gee, 2000).

The concept of STEM (science, technology, engineering, and mathematics) identity explores the ways in which individuals strive to align themselves with STEM areas by interpreting their experiences in science in accordance with societal perceptions of what constitutes STEM (Carlone and Johnson, 2007; Hughes et al., 2013). The research on STEM identity formation has demonstrated its potential as a metric for assessing an individual's involvement and active involvement in STEM disciplines (Chelmers et al., 2011). Nevertheless, the absence of adequate representation in STEM educational settings might have a significant impact on the formation of STEM identity among marginalized students (Singer et al., 2020). The study conducted by Tate and Linn (2005) aimed to investigate the perspectives of five female individuals from ethnic minority backgrounds within the field of engineering. The examination of the interview data revealed the emergence of three distinct identities (academic, social, and intellectual) that contribute to the comprehension of how undergraduate students operate in different contexts. Furthermore, it shed light on how these students manage and traverse their many identities inside their respective educational institutions. The study's results revealed that the participants, who were women of color in the field of engineering, possessed robust academic identities. However, their identities were impeded by a perceived absence of belongingness in comparison to their White counterparts.

The absence of acknowledgment within the discipline might have implications for underrepresented students, particularly those from racial and ethnic minority backgrounds, in terms of their perceived inclusion in STEM disciplines that are unique to content areas (Rainey et al., 2018). Moreover, previous studies have demonstrated a significant relationship between the self-conceptualization and development of disciplinary identities among historically marginalized students, and their levels of interest, persistence, perception, recognition, and success within postsecondary STEM contexts (Tan, 2013; Hazari, Sadler, & Sonnert, 2013; Kang, 2018).

Perception and Recognition

Within educational settings focused on science, technology, engineering, and mathematics (STEM), the formation of a STEM identity can be understood as a social identity that is rooted in the individual's affiliation with a certain STEM discipline or field (Kim et al., 2018). The existing body of research has yielded empirical evidence pertaining to the experiences of students in the fields of science, technology, engineering, and mathematics (STEM). Researchers have expanded their investigations to focus on the influence of STEM identities on the perception and recognition of students from racial and ethnic minority backgrounds in STEM courses (Hazari et al., 2013; Jones, 2020; Starr, 2018; Tate & Linn, 2005; Williams and George-Jackson, 2014). The engagement and retention of students in STEM areas are influenced by their perceptions, observations of STEM, and external circumstances related with these perceptions. The influence exerted by one's social group plays a significant role in shaping the factors that affect an individual's engagement in STEM fields, as evidenced by the encouragement received.

The notions of perception and recognition are located within the framework of power, as discussed by Gee (2000), who explores the source of this power. Therefore, the act of pursuing membership in a group, as well as the acknowledgment and acquisition of membership itself, hold a distinct significance. The acknowledgment of an individual's status is contingent upon the institutionalized mechanisms that govern the distribution of power dynamics. In their ethnographic study, Carlone and Johnson (2007) examined the process of science identity formation among a group of 15 women belonging to racial and ethnic minority backgrounds. A science identity model was developed, comprising three distinct components: performance, competence, and recognition. The authors employed a conceptual model to discern the intricacies associated with the development of a science identity among women. The authors stated that the concept of "recognition" presented inherent challenges, as it was influenced by external variables that were beyond an individual's control. The achievement of women of color in STEM professions was impeded by the intersectionality of their gender, ethnicity, and cultural backgrounds. In essence, the impact of these structures governs the standards, preconceived notions, and archetypes that individuals strive to acquire. In the context of STEM fields, it is important to acknowledge that certain groups of students, particularly those who are underrepresented, may encounter institutional barriers based on factors such as race, ethnicity, and gender. These barriers can function as gatekeepers within the STEM community, impeding individuals' ability to be perceived and recognized in STEM courses. This observation is supported by previous research conducted by Carlone and Johnson (2007), Harzari et al. (2013), Linn and Tate (2005), Morton and Parson (2018), and Nealy and Orgill (2020).

STEM Identity and Learning Environments

There is a paucity of research on the development of pedagogical practices and spaces to support the learning and development of students of color in postsecondary STEM contexts. The primary factor contributing to this phenomenon can be attributed to the fact that STEM disciplines are predominantly founded around Eurocentric models and theories. According to Ortiz et al. (2020), historically, STEM learning environments have not fostered the formation of historically marginalized populations' identities or validated their cultural knowledge, which has resulted in a dearth of SoC (Students of Color) representation in STEM areas.

Students belonging to marginalized racial and ethnic groups, commonly referred to as Students of Color (SoC), encounter challenges in reconciling their personal identities, interests, and self-perceptions within the intricate and conflicting dynamics of STEM environments, which frequently fail to match with their cultural perspectives. As noted by Jones (2020), students from diverse racial and ethnic backgrounds, commonly referred to as Students of Color (SoC), face the challenge of reconciling their personal interests, determination, sense of belonging, and individual identities with the dominant Westernized perspectives and methodologies prevalent in STEM fields.

Hence, the scholarly discourse emphasizes the necessity of developing programming and allocating resources that cultivate an inclusive atmosphere, so facilitating the retention and persistence of marginalized students in STEM courses (Atkins et al., 2020; Morton, 2018; Ortiz et al., 2020; Starr et al., 2020). In particular, marginalized STEM students find it challenging to use their positionality to their advantage and establish connections to their intersectional identities and lives in STEM classrooms (Avraamidou, 2020). Therefore, it is imperative that contributions from the field first present a range of perspectives and techniques within STEM contexts and disciplines. Creating culturally appropriate environments and procedures that support SoCs in developing their STEM identities and encourage their interest in and perseverance in the field is the duty of educational scholars and practitioners.

Method

A nested mixed methods approach was used to examine incoming underrepresented STEM scholars' perceptions and beliefs about STEM and their professional choices of major and career. Mixed methods research allows the researchers to use both qualitative and quantitative measures to provide for an all-encompassing analysis of the experiences of the participants (Creswell & Creswell 2018). The primary methodological focus was qualitative. Creswell (2002) describes qualitative research as an inquiry that can interprets meaning by drawing from personal experiences. Nested within the qualitative approach was a quantitative one. Quantitative research used in this study explored the relationship between the participants ideals and beliefs of perception of STEM through survey data. These data points were used, but in a manner to guide the qualitative interpretation to provide a holistic perspective the scholars perceptions.

Participants

This study took place at a large research-intensive university in the Midwestern United States. The participants included eleven incoming undergraduate students from across the Midwest United States. The participants were recruited from a summer research program for incoming undergraduate students from underrepresented populations that were selected for STEM areas of study. According to students' self-identified data, the population was 72 % female, 27% male, 36% Black/African American, 36% Hispanic/Latinx, 9% Asian, and 9% Multi-ethnic (e.g., two or more races) and 9% White. Intended majors across STEM fields consisted of 82% in science, 9% in technology, and 9% in engineering, and none in mathematics.

Data Collection

Data collection included survey, a STEM perceptions activity, and written student reflections. Collecting qualitative and quantitative data ensures that the nuances associated with the participants' attitudes, beliefs, and perceptions about STEM were captured. Before analysis, all data sources were sent to a transcription service for transcription (see Appendix).

Survey Instrument. A survey of perceptions, beliefs, and attitudes surrounding STEM was administered the first week of the summer. The survey was adapted from Chemers et al.'s (2011) role of efficacy and identity in science among underrepresented minority students to explore physiological factors (e.g., perceptions, attitudes, and beliefs) influencing students' retention in STEM courses. The survey consisted of 30 questions scored on 1-5 Likert scale-type responses. We specifically examined factors science self-efficacy, identity as a scientist, and commitment to science careers due to their close alignment to the framework for this study.

STEM Perceptions Activity. An activity designed to facilitate the students in identifying their STEM perceptions and how they were formed was conducted with all eleven participants during the second week of the summer. This activity was adapted Friedrichsen and Dana's (2003) card sort task. The researchers consulted the literature to identify scenarios that were considered traditional and indigenous beliefs of STEM. Participants were asked to separate each card into three different piles that reflect their perceptions and views and provide their reasoning during the activity.

Students Reflections. Written student reflections through journaling was a crucial tool for figuring out the intricacies of the learning process. The researchers encouraged students to engage in journaling for them to articulate their beliefs and views concerning the card sort task and the challenges that occurred when interpreting what constitutes those scenarios as STEM.

Data Analysis

For this study, a variety of data analysis methods were used to explore the influence of student's perceptions on their STEM trajectories and careers. Quantitative data from the survey was analyzed through descriptive statistics. Student responses from the survey data included the measures of central tendency (mean) and measure of dispersion accounted for pre and post card sort activity to inform the qualitative data. To ensure that student's voices were accounted for the data points where integrated into the qualitative data and thematic analysis was applied (Braun and Clarke, 2006). Throughout the process, all data points were systematically organized and supported by the use of ATLAS. Ti 7.0, qualitative software. Initial open coding was utilized across data points to determine if the types of codes were representative of the data. The authors met to review the codes and revise them as necessary. Afterwards similar codes were collapsed and merged and once several iterations of the data were applied categories and themes emerged building a picture of students' perceptions of STEM, supported with direct quotations from the participants.

Results

The findings from this study illustrate how the academic and career choices of historically marginalized undergraduate students are influenced by their perceptions of STEM. As a comprehensive analysis from the card sort activity, student reflections, and survey data aligned with each research question we highlight the variations in students' ideals of STEM in their own words.

Research Question 1: How do historically marginalized students perceive STEM?
STEM is Task Oriented

When exploring perceptions of STEM, the students expressed that for activities to be considered STEM it must be task oriented. Many of the students relied on prior knowledge from society, peers and family in their definition of STEM. In defining STEM begin oriented, a requirement of the activity had an element of process leading to an outcome in which they believe to be novel or productive. This definition also included elements from the MMRE survey that aligned with their perceptions of STEM. These questions were related to the ideals and societal beliefs that in order for activity to be considered STEM an individual would have to able to have the skills and confidence perceived to be successful in STEM.

Table 1 provides pre and post card sort activity statistics for science self-efficacy. The means ranged for science self-efficacy ranged from 2.73 to 3.27 pre card sort activity, with a standard deviation from 0.54 to 1.19. However, after the card sort activity and discussion a shift occurred with means increasing from 3.29 to 4.14, with standard deviations ranging from 0.69 to 1.1.

Table 1. Descriptive Statistics for Science Self-Efficacy (n=11)

Item	Pre		Post	
	M	*SD*	*M*	*SD*
Science Self-Efficacy				
Use technical science skills (use of tools, instruments, and/or techniques)	3.27	0.90	3.29	1.11
Use scientific literature and/or reports to guide research	2.73	1.19	4.14	0.69
Use scientific language and terminology	3.00	1.00	4.00	0.82
Figure out what data/observations to collect and how to collect them.	3.09	0.54	4.00	0.76
Relate results and explanations to the work of others.	2.82	0.98	4.00	0.82

Many of the participants identified STEM through a task orientation lens, but did not equate in relatability to the concept. As shared by one student, *STEM to me is just what the abbreviation spells out which is science, technology, engineering, and mathematics*. Another student expressed similar thoughts such as: *To others I feel that they just associate the word with science and studying something in that realm.* During the post discussion many of the students expressed through their prior knowledge their reasoning behind the choices of the card sort. One student expressed, STEM *standards is like working in the lab, medicine, or in technology, but also in anything that includes data collection or mathematical techniques*.

Others shared that *STEM includes tasks that requires math, computation, hypothesizing, questioning, research, critical thinking.* For many, their perception of STEM included ideals that individuals needed certain skills in order to complete a STEM directed tasks (e.g., problem solving, computation, mathematical skills). The students seemed to only highlighted those skills due to their own experiences in developing these tasks. As shared by a student during the classroom discussion, *I feel like a lot of these cards lack the actual analyzation that you need like problem-solving, developing, communication, cooperation, creativity, invention, and creating something.*

These tasks directed skills in which many of the students highlighted were ones in which others felt that they lack. Those that felt that they were not provided the initial background needed to be successful in STEM did believe they could obtain the necessary knowledge needed to be recognize in STEM spaces. For example, one student reflected: *Well, I don't feel skilled, I could say. But I do feel like I'm very knowledgeable of what I'm doing most of the time.* Other students expressed that despite the lack of the skill that their peers felt they could still be successful in STEM.

> *But I feel that in STEM you can do so many different things. Each time that you go do something in STEM you can learn something new, so every time I got to class, I feel that I am learning something new and enriching. So, I don’t think it’s not skill based but more like increasing my knowledge which is skill.*

Participating in card sort tasks provides students with an overall perception of STEM and highlights the importance of task-directed skills for success in the STEM field. The tasks identified by the students necessitated performance involving explicit instructions, such as mathematical equations and computer coding. Throughout the activity, students gradually articulated their evolving understanding of how to cultivate these skills. In addition, the students brought attention to the fact that possessing skills alone is insufficient for achieving success in STEM.

Research Question 2: What experiences do historically marginalized students identify as having an impact on their perceptions of STEM?
External Ties That Bind STEM Together

Changes in the students' understanding of STEM became apparent as they participated in the card sorting activity. During the activity, the students conveyed through classroom discussion and survey data that their thinking about STEM was influenced by external experiences. Students classify these external connections as familial and possessing a cultural consciousness that they employ to comprehend STEM.

Family Ties

As discussion began many students took into consideration the familiar connections to the STEM field. In particular, a focus on the parent's aptitude was defined by the students to include the ability to help students in coursework or their thoughts and feelings concerning them entering into STEM fields. One student shared, "*The cards that talked about coding and video games to me were more like STEM. My dad was a mathematics major before we fled our home country, when we arrived in the United States, father never did not complete his degree, but he encourages me to major in computer science."*

*O*ther students highlighted how a lack of parental aptitude towards STEM influenced their perception of STEM. "*My mom told me to just go STEM. So, yeah, no, none of my families involved them, actually, when I came here, they were like, what is that? They don't even know what it is.*" Another student shared a similar experience regarding their parents' aptitude towards STEM: "*Never, they never really talk about STEM. I personally grew up in a Hispanic culture, So, I think they are really not really keen on STEM stuff. They were not really exposed to it or really know what it means."* In addition, students were able to make connections in the ways in which students might hold a negative perception of STEM as mentioned by a student, *"Many reject science because of their religion, upbringing, or tradition. Children who are influenced by their parents may see science as an evil force that seeks to change their ideas and beliefs. That may affect how kids learn in the classroom."*

The Power of Culture

During the discussion of the card sort activity students made connections on the value of recognition of STEM and culture awareness from the card sort. For students, having a cultural link to STEM aid in their determination of which card sort tasks were considered STEM one student expressed, *in some ways, culture can impact my learning of STEM. Others might classify STEM, as a simply rigorous career path. To me STEM is a way to help the world and find these answers to make the world and humanity better."* As they progressed through the activity, students further expressed their ideals of culture and their perceptions of STEM in classroom environments. *"Culture can impact my learning of STEM in the classroom environments because if not comfortable or if I am in a negative environment how am I going to be confident in learning and discussing new things*." Overall, students expressed how specifically how cultural intersects with racial perspectives during post discussion of card sort activity:

> *Culture can definitely impact ones learning of STEM not just in the classroom, but outside of it as well. Generally, there is this lack of confidence towards people of color in STEM fields, and even more when it comes to women in the studies. This can cause difficulties in the classroom because other students might receive more help based on the lack of confidence the instructor has in the students of color.*

While students were able to share the impact that culture has towards an individual perceptions of STEM other students challenged the ideal of culture being an influence of their perspective of STEM. One student shared, *"Culture wouldn't really have an impact on STEM as it is science and there are not much cultural effects it can have."* The student further expressed their perspective was rooted in more traditional western society lens. For instance, one student stated the following excerpt:

> *"I still think society decides and what is STEM or not. We have a long-standing perception of what STEM is, and for most, the first thing they think when they hear science is the traditional working in the lab. I only know this because growing up this was the perception of STEM I was given. Even when it came to science, I was taught experimentation always ways ended with a calculated outcome, but research, in reality, is much more tentative."*

Students demonstrated an ability to acknowledge how external influences, such as family and culture, could either challenge or validate their perceptions of STEM. Throughout the lesson, students recognized the intricate ways in which these factors intersect and how they can be influenced by racial and societal expectations. Moreover, this realization prompted students to actively acknowledge the challenges of being part of a marginalized community in STEM learning environments. Consequently, students were able to engage in more profound introspection regarding their perception of STEM and its impact on their participation in STEM fields through the exchange of personal experiences.

Research Question 3: Do historically marginalized students' perceptions of STEM influence their academic and career choices?

Remaining Hopeful, But Aware of The Journey Ahead

The study included students whose perceptions of STEM could potentially influence their future path in the field. The analysis of the survey data, card sort protocol, and classroom discussion revealed a recurring theme of maintaining optimism while also acknowledging the realities of being in the STEM field. As a result of the activity, students were able to articulate their future dedication to STEM and the potential challenges they may encounter while pursuing a STEM degree.

In Table 2 explored students' commitment to a science career. Questions asked expressed the attitudes of students' future aspiration in STEM fields after degree completion potential towards retention and participation in STEM fields and courses. Pre card sort activity the mean ranges from 4.18to 3.91 with a standard deviation from 1.27 to 1.87. However, post activity intervention the means across the question set shifted to range from 4.14 to 4.29, with standard deviations ranging from 1.46 to 1.57.

Table 2. Descriptive Statistics for Commitment to a Science Career (n=11)

Item	Pre		Post	
Commitment to a Science Career	*M*	*SD*	*M*	*SD*
I intend to work in a job related to science	3.91	1.87	4.29	1.50
I see the next steps in the field of science and I intend to take them	4.18	1.27	4.14	1.57
I expect a career in this field will be very satisfying.	3.91	1.64	4.29	1.50
I feel that I am on a definite career path in science.	4.00	1.55	4.14	1.46
I definitely want a career for myself in science.	4.09	1.58	4.29	1.46
Science is the ideal field of study for my life.	4.09	1.58	4.29	1.50

In table 3 the descriptive statistics on how an individual seeks value in identifying a scientist were highlighted across pre and post card sort activity. Across these questions a focus of self-image, sense of belonging, beliefs, and importance to the scientific community were highlighted. Pre card sort activity the means ranges between 3.27 to 2.36 with standard deviations from 1.10 to 1.54. After the card sort intervention means ranged from 4.13 to 3.43 with standard deviations from 1.13 to 1.62.

Table 3. Descriptive Statistics for Identity as a Scientist (n=11)

Item	Pre		Post	
Identity as a Scientist	*M*	*SD*	*M*	*SD*
In general, being a scientist is an important part of my self-image.	3.27	1.10	3.57	1.27
I have a strong sense of belonging to the community of scientists.	2.91	1.30	3.43	1.13
Being a scientist is an important reflection of who I am.	2.73	1.10	3.57	1.27
I have come to think of myself as a "scientist."	2.36	1.21	3.57	1.62
I feel like I belong in the field of science.	3.73	1.42	4.14	1.46
I am a scientist.	2.82	1.54	3.86	1.57

Across these survey questions students were able to highlight a positive outlook towards being in STEM using their experience from the course. One student shared "*My answer has changed from last time. STEM is much more inclusive to everyday things than I ever thought of before. STEM is much more than mathematical equations and coding. It could be from the simple skills that we were taught at from home."* Students were able to express excitement in knowing that they were able bring their knowledge into the STEM spaces as an aid in their understanding of STEM.

When it came to making connections to their academic choices as STEM majors the stark reality of the difficulties that could occur was made aware by the students. One student shared, *STEM "I believe is still a certain lifestyle and an area for innovative people. It's also an area in which minorities and people of color are under-*

represented." Additional feelings of intimidation from students were described below:

> *"Any career STEM based is particularly male dominated. As a young woman, that definitely intimidates me and causes me doubt. Like, "Am I going to be able to do this? "Maybe this isn't the career path for me. Maybe I'm not smart enough like them. But I believe the real strength and intelligence comes from pushing forwards and growing past those doubts."*

The students' feelings of underrepresentation or marginalization were less pronounced before the card sort activity. However, the students were able to identify due a lack of representation within STEM course and fields has influence on the ways which they see themselves within STEM. As shared from a student, *"they probably think it's about intelligent people. I also think a lot of people aren't aware of what STEM is and aren't interested in it."*

A lack of engagement as being related to a lack of diversity among their courses, and this gap led to a critical grasp of what it means to be underrepresented in STEM. As stated in her diary, the instructor wished for the students to understand the broader ramifications of being a part of an underrepresented population necessitates a voice that supports a student-centered experience:

Throughout the activity, the students' self-reported data indicated a growing sense of belonging and positive self-image, suggesting an increasing confidence in being acknowledged as a scientist. Nevertheless, when students were given the chance to engage in a more in-depth conversation about their future paths in STEM, they openly recognized their reservations and obstacles. This acknowledgment underscores the fact that marginalized students in STEM educational settings encounter this issue and its impact on their future. Nevertheless, the students conveyed their willingness to confront these challenges, as their aspiration to be involved in STEM fields and pursue careers outweighs any potential negativity associated with their academic decisions.

Discussion and Conclusion

Within this study we highlighted the ways in how marginalized students perceive STEM and its influence on their future STEM academic and career choices. Prior research has demonstrated that when students are able to comprehend and apply STEM concepts, as well as acquire essential scientific abilities, they are able to form a distinct sense of identity in the STEM field (Hughes et al., 2013; Singer et al., 2020). Although the survey data collected before and after indicated a rise in the feeling of belonging and attitudes towards their understanding of STEM, the responses obtained from the card sort at times were just as nuanced as the participants. The relationship between the development of STEM identity and the connection between a sense of belonging, participation, and retention is intricate and subtle (Avraamidou, 2020; Jones, 2020; Morton, 2018; Ortiz et al., 2020). However, we aimed to stimulate students' awareness of the relationship between their perceptions and their experiences in STEM.

Notable shifts in pre- and post-assessment responses underscore the heightened importance placed on self-image, a sense of belonging, personal beliefs, and perceived significance within the scientific community. In this study it is concluded that students' self-efficacy in science revealed an emphasis on the valorization like the researchers Carlone and Johnson (2007) science identity development focused on performance and competence. These constructs emerged among marginalized students expressed as skills that they initially perceived are valued within the scientific community.

Examining the concepts of in relation to students' confidence in their scientific skills, a significant discovery arises: students do not simply conform to the STEM environment for social inclusion. Instead, they introduce pre-established identities that are strongly linked to perceptions of capability and societal norms. This was acknowledged throughout the study as students held to the prevailing narrative that conforming to prescriptive ideals of STEM is needed in order to be accepted in STEM fields and careers.

Previous studies have established that students from underrepresented groups require opportunities that prioritize their experiences from a perspective that is not Eurocentric (e.g., Collins,2018; Jones, 2020). Complex dynamics revealed by our study regarding how underrepresented students perceive STEM fields and the resulting impact on their academic and career interests. As seen across the literature, recognition, construed as a construct susceptible to external influences, emerges as a formidable challenge for marginalized students in STEM (Avraamidou, 2020; Dou et al.2021; Hazari et al.2021).

It has been found that literature that as students' exposure to STEM fields is a key factor in maintaining sustained interest in STEM fields. The exploration extends further into the external determinants shaping students' perceptions of STEM, with an emphasis on the familial and social sphere. However, a significant finding comes to light: conceptions of STEM are firmly established within a conventional Westernized paradigm, which in turn influences preferences with regard to academic majors and professional fields. The card sorting activity highlights a proclivity for traditionally valued majors and alludes to a potential gap in exposure to a variety of STEM-related is needed in order to be accepted in STEM fields and careers.

This study's findings have important implications for both educational practitioners and policymakers. To begin, the fact that marginalized students bring pre-existing identities into STEM spaces emphasizes the importance of pedagogical approaches that promote inclusivity and recognize diverse perspectives. Curricular interventions should strive to challenge conventional stereotypes and create an environment in which students' self-perceived competencies are validated and developed. Furthermore, the discernible impact of familial and social influences on students' perceptions of STEM highlights the importance of collaborative efforts between educators and families to provide a comprehensive support system. Initiatives aimed at exposing students to a variety of STEM scenarios during secondary school are critical for broadening students' horizons and mitigating the influence of traditional Westernized paradigms.

Future Directions

This study underscores the imperative of integrating role models and diverse representations within STEM education to confront entrenched misconceptions. Recognizing the challenges posed by external influences on the recognition of underrepresented students in STEM, academic institutions and policymakers must proactively implement measures to mitigate these barriers. Future research endeavors could delve deeper into the long-term impact of interventions aimed at fostering a sense of belonging and challenging traditional perceptions of STEM. Exploring the effectiveness of pedagogical strategies in reshaping students' self-efficacy and dismantling stereotypes could offer valuable insights into creating more equitable and inclusive STEM learning environments. Additionally, longitudinal studies tracking the career trajectories of underrepresented students who have undergone such interventions would contribute to a comprehensive understanding of the enduring impact on their academic and professional pursuit.

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Appendix. Data Collection Tool

Student Name: ___________________________
Date: ___________________________________
Interviewer's Name: ______________________

Purpose: When trying to identify Science, Technology, Engineering and Math (STEM) research would argue about the definition and the measures associated with the term. Today we will be interviewing each other about our ideas and beliefs on what constitutes STEM.

Instructions:

A) Open Kaltura Personal Capture on your computer. Do not start recording yet.
B) To begin, create a pseudonym (false name) for the person that you will interview and write their name above. (Please make sure the name is appropriate)
C) Begin Recording on Kaltura Personal Capture on your computer and ask the baseline questions listed below (See questions below).
D) You will complete a card sort task and ask the questions that are bolded to your participant.
E) End the recording and save it as the pseudonym name and today's date. E.g. Molly_6-21-22
F) Submit the audio interview recording to canvas.

Baseline Questions Prior to Card Sort:
Start the interview by asking the following questions below. Under each question take down notes to make sure that you are capturing the important information just in case something happens while you record.

1. What has your experience been in school with courses/classes in science, technology, engineering, and math (STEM)? (Please let the interviewee know that we will call this area STEM at this point.)

2. How skilled do you feel in your STEM classes? (Please elaborate.)

3. Are any of your family members involved in a STEM-related career? What type of work do they do?

4. How do your parents or guardians feel about STEM fields in general? To what extent do they talk about science and technology at home?

Card Sort Task Instructions: Work in Pairs: selecting one as the interviewer and the other as a student. The student sorts the scenario cards into three stacks: (a) this scenario represents how I think about STEM, (b) this scenario does not represent how I think about STEM, and (c) unsure.

Interviewers say the following statement: Now we are going to move onto the card sort task. Here is a pile of 10 cards. I'd like for you to sort them into three piles ---

1. **YES, for those you feel the scenario represents how you think about STEM.**
2. **NO, for those scenarios that do not represent how you think about STEM.**
3. **MAYBE for those you think could be STEM if you could modify it in some way.**

As you are sorting the cards, I will ask you a few questions about why you are putting certain cards into particular piles, what modifications you might make to the MAYBE cards, etc. Do you have any questions before we begin? O.K. let's get started then…here you go.

Pass the 10 cards to the student, as they begin sorting verify which pile is their Yes, No, and Maybe so you know which column to record the card number in. Please write one card number per row below.

Yes	No	Maybe	modifications for maybe cards

As the individuals are sorting the cards ask the following questions:

- Card 1 – **can you tell me why you decided to place that in the "___" pile? What is it about this scenario that you** ---- [*select the one that matches what they did*] ---a**gree with/don't agree with/think you would maybe be STEM?**

- Card 2 – **What is it about this card that makes you place it in the same/different pile from the previous card?**

- Card 3 – *just let them sort this one – no question – UNLESS they put it in the "maybe" pile and then ask: "***What would you want to modify in this card before you would agree that you might about this topic in this way?"**

- Card 4 - **What is it about this scenario that made you decide to place this card in the "____" pile?**

- Card 5 - *just let them sort this one – no question – UNLESS they put it in the "maybe" pile and then ask: "***What would you want to modify in this card before you would agree that you might think about this topic in this way?"**

- Card 6 - **can you tell me why you decided to place that in the "___" pile? What is it about this scenario that you ---agree with/don't agree with/think you would maybe do?**

- Card 7 - **What about this card that makes you place it in the same/different pile from the previous card (#6)?**

- Card 8 - *just let them sort this one – no question – UNLESS they put it in the "maybe" pile and then ask: "***What would you want to modify in this card before you would agree that you might think about this topic in this way?"**

- Card 9 - **What about this scenario made you decide to place this card in the "____" pile?**

- Card 10 – **Is there something about this card that reminds you of the other cards you placed in this same pile? Is this the reason that you placed this card in this pile? Or was it for another reason?**

Once the individuals have sorted the cards into the three piles, carry on with the following questions.

Looking at just the cards in your "Yes" pile, is there one that stands out to you as something you believe represents STEM the best?

Looking at your "No" pile, is there something that you think these cards all have in common?

Could you explain why you don't think these cards represent STEM in your opinion?

Looking at the cards you put in the "MAYBE" pile and thinking about what you said you might do to modify each before you would label it STEM *(you may need to share some of these ideas from your notes in the chart with the student)***, was there something consistently lacking in each scenario that you felt was critical towards connecting with STEM?**

Cards for Card-sort task.

M Card #1 The seasons are changing, and you need a warm blanket for your bed to keep out the cold. You find a fabric and begin to quilt a blanket. You finish the quilt right before the first snowfall.	M **Card #2 - Painter** It is spring break, and you want to make extra cash. Your local painting company is hiring painters to assist with painting homes that have been remodeled.
M **Card #3** Fishing is a significant practice for Torres Strait Islander women. Women are expected to provide their family relations with fish of reasonable size and type. The idea is to ensure that buckets have sufficient fish for each family, however, this does not mean that each bucket will have the same number of fish. Here, same is not based on amount, rather it is the size of the family and ensuring that each family member receives food.	HS **Card #4** You notice you have a headache that will not go away with taking meds. So, you set up an appointment with an acupuncturist to assist with reducing your headaches.
E Card #5 You noticed you have gained a little weight from eating a lot of processed food. To lose weight, you have decided to start your own garden. In the garden you grow seasonal fresh fruits and vegetables.	A **Card #6** During your science class, your teacher speaks about the upcoming lunar eclipse that is happening today. Your classmate begins to tell a story that she heard from her grandmother. *The lunar eclipse is an omen for death for men. If the moon is hungry and wants to eat someone (a man) it becomes dark. But women need not to fear because the moon doesn't eat women.*
B Card #7 You have developed a summer cold during summer camp. You called your grandma and she reminded you of the homemade remedy that you took at home that included honey, vinegar, and hot water. You make the remedy and drink for the next three mornings. After those days you start to feel better.	**c s Card #8** Playing your favorite game on your gaming system you discovered that you could code your game to unlock a hidden world. After you figure this out you start selling your game codes to your friends so they can play the hidden levels as well.
P/E Card #9 While being on a traveling soccer team, you notice that when you play on different surfaces (i.e., grass, turf, and parking lots) that your cleats aren't as effective in helping you score points. As a result, you begin to wear different cleats depending on the surface while playing soccer.	**M/E Card #10** You just completed a home-building project. In the next phase of the project, you have to figure out how much flooring to place throughout the house. You contact the flooring installer to find out the cost.

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